(12) UK Patent Application (19) GB (11) 2 301 328 (13) A

(43) Date of A Publication 04.12.1996

(21) Application No 9610541.6

(22) Date of Filing 20.05.1996

(30) Priority Data
(31) 9510768 (32) 26.05.1995 (33) GB

(71) Applicant(s)
Syntron Inc

(Incorporated in USA - Texas)

17200 Park Row, Houston, Texas 77084-4925,
United States of America

(72) Inventor(s)
John Luscombe

(74) Agent and/or Address for Service
Michael Stanley & Co.
86 Warwick Road, Banbury, OXON, OX16 7AJ,
United Kingdom

(51) INT CL[6]
G01V 1/20 , B63B 21/66

(52) UK CL (Edition O)
B7V VHS
F2P PA13 PC10 P1B7E
U1S S2141

(56) Documents Cited
WO 93/03402 A1 US 4951265 A

(58) Field of Search
UK CL (Edition O) B7V VHS , G1G GEEA GEEH
INT CL[6] B63B 21/66 , G01V 1/18 1/20 1/38
Online:WPI

(54) **A Seismic Streamer**

(57) A seismic marine streamer 10 comprises hydrophones 12 housed in elongate flexible tubes 11, a pair of load carrying rope members 25, 26, and a plurality of spacers 15 which substantially fill the internal cross-section of the tube 11, the internal void within the tube being filled by liquid, wherein the two rope carrying members 25, 26 interconnect end fittings 21, 22 located at each end of the tube 11, and pass through each spacer 25 on diametrically opposite sides thereof adjacent the outer peripheral margin of said spacer.

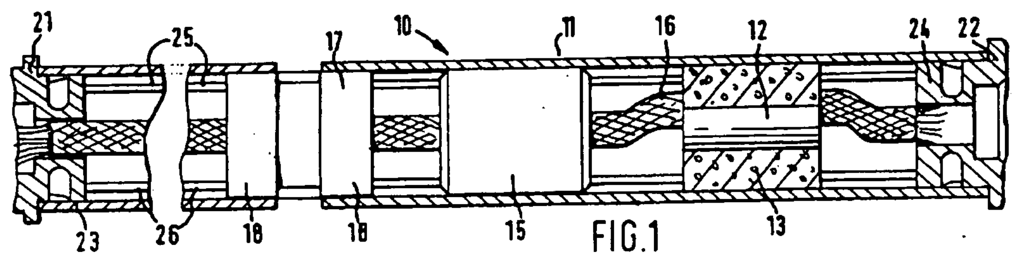

FIG.1

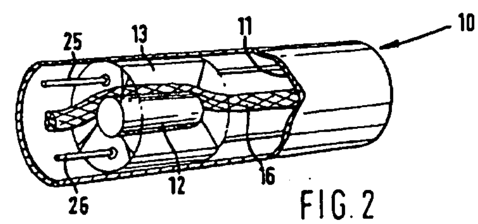

FIG.2

GB 2 301 328 A

1/5

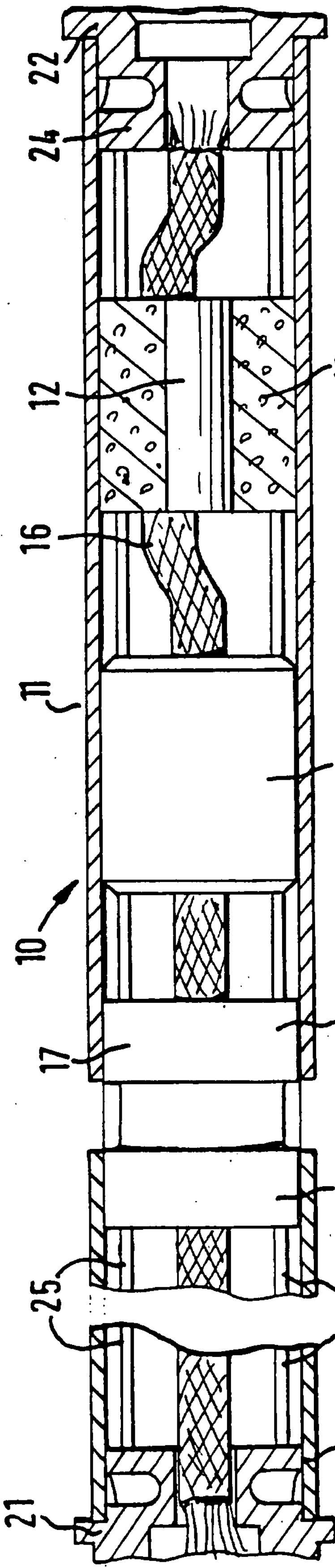

FIG.1

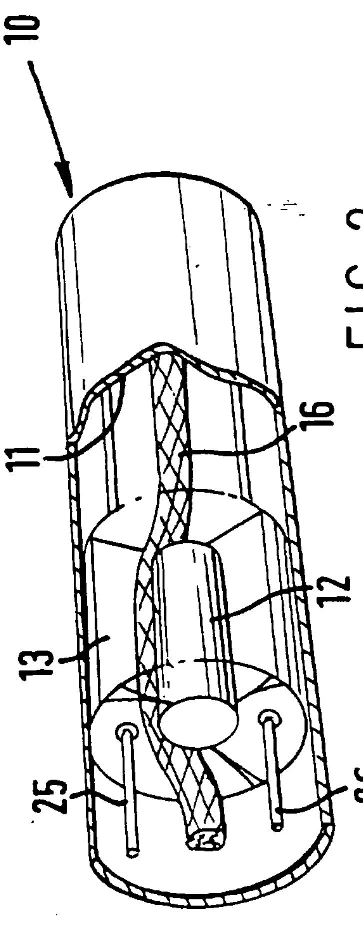

FIG. 2

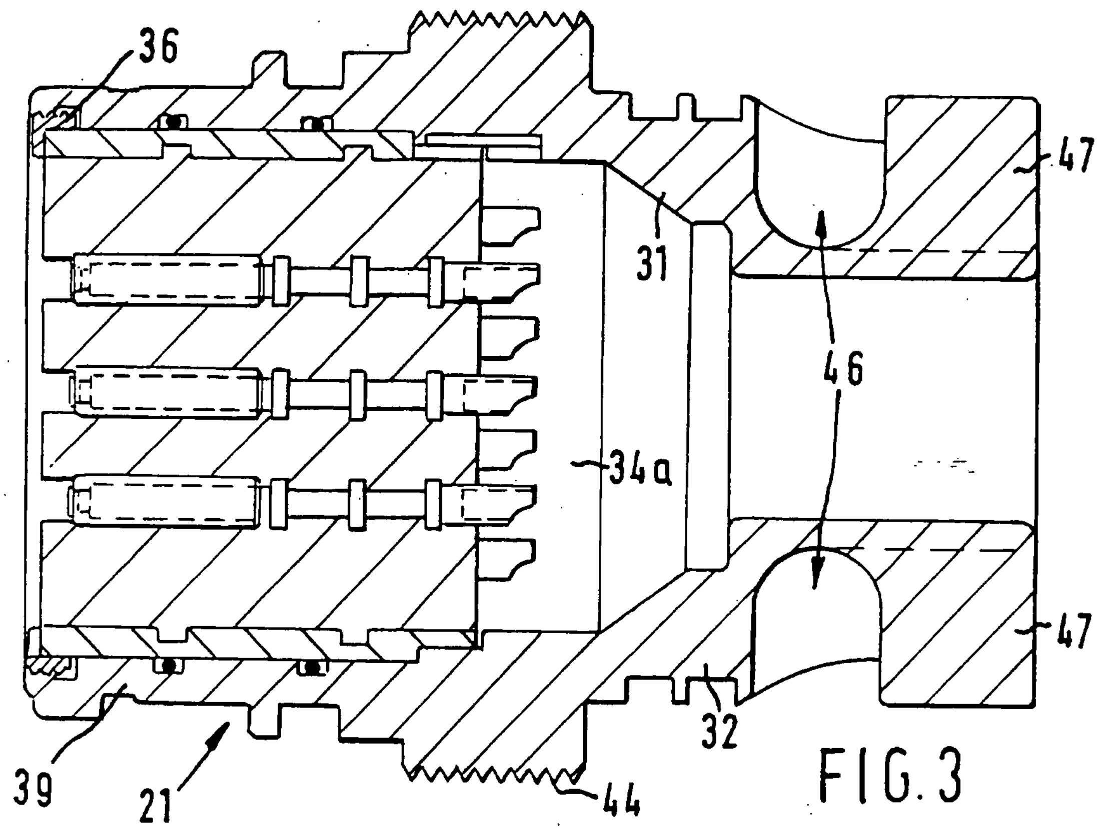

FIG. 3

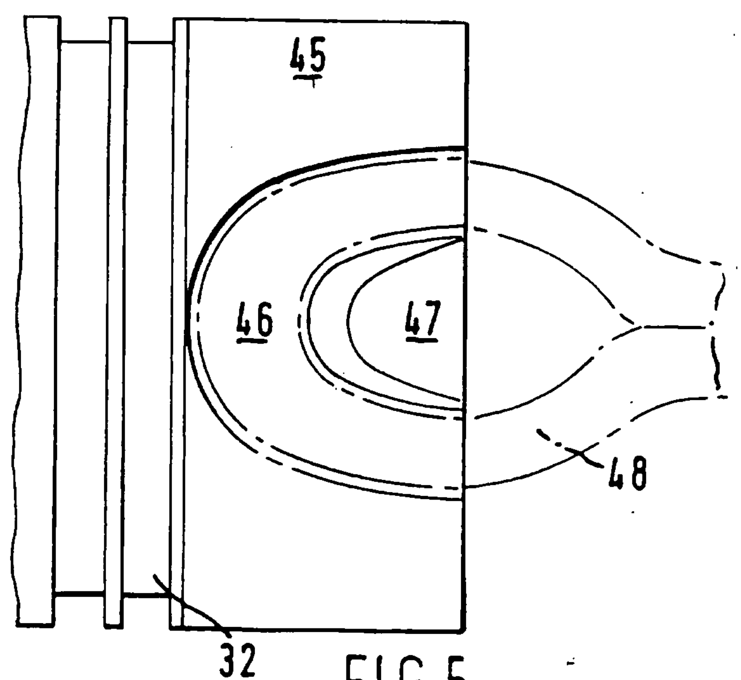

FIG. 5

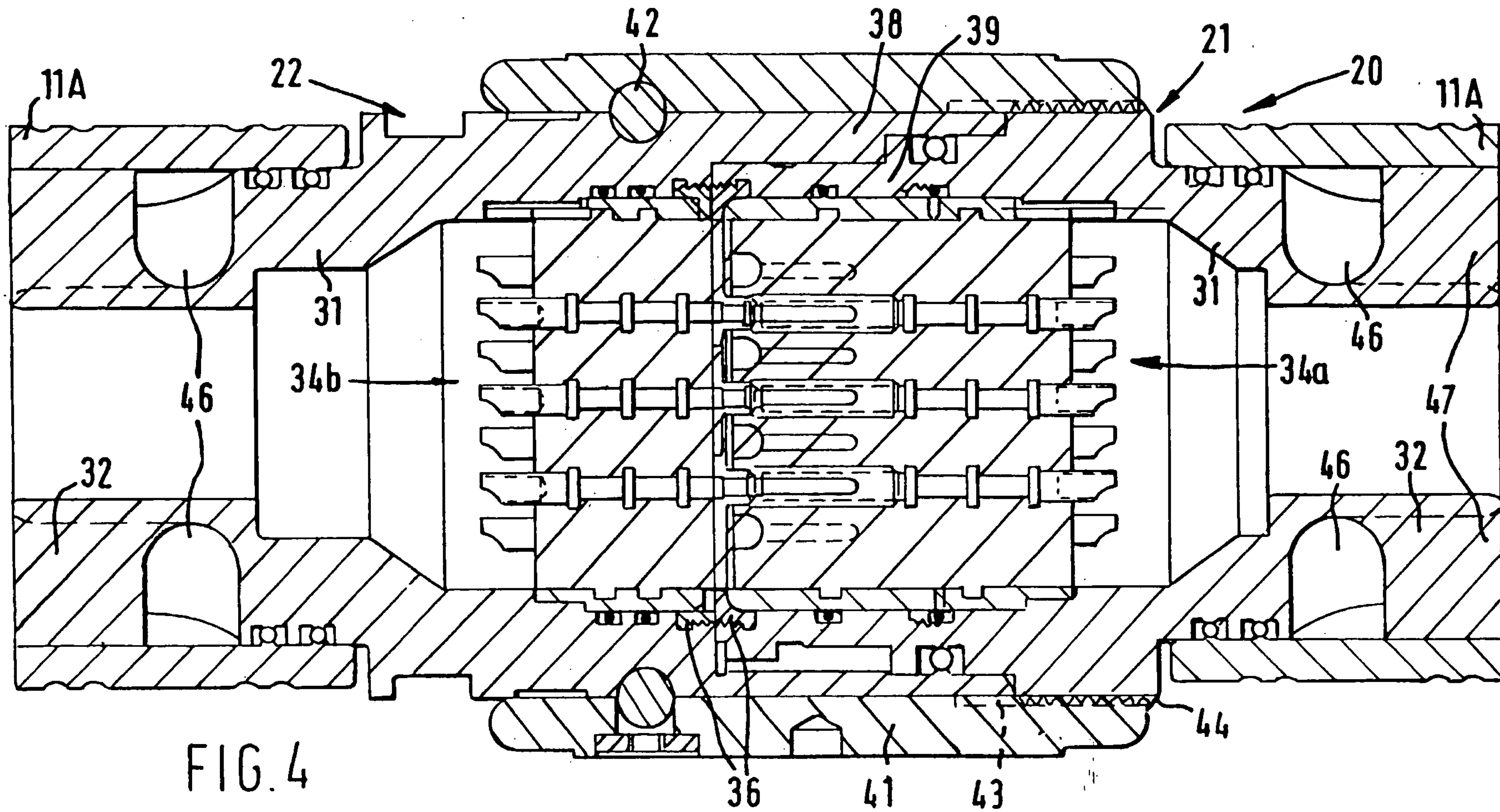

FIG. 4

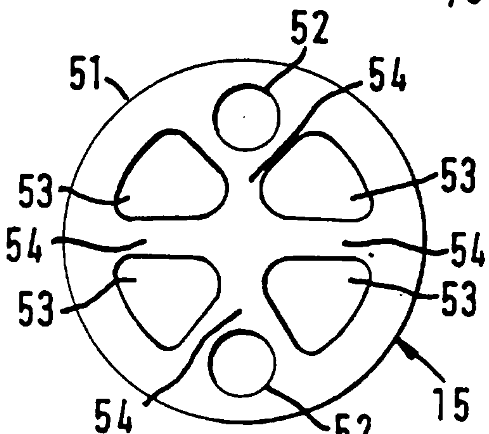

FIG.6

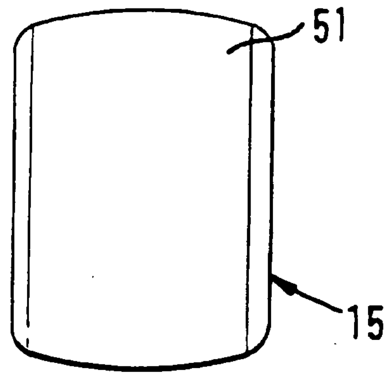

FIG.7

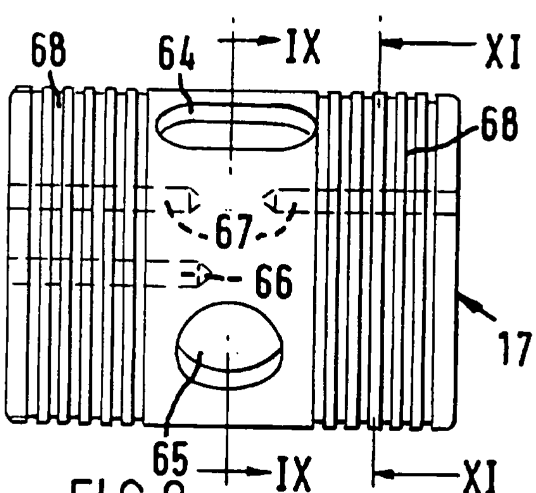

FIG.8

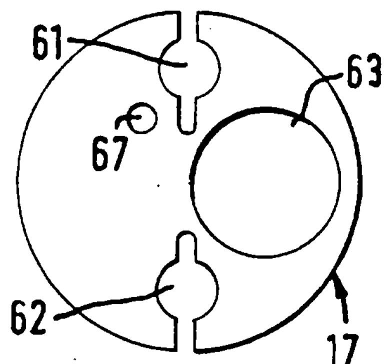

FIG.11

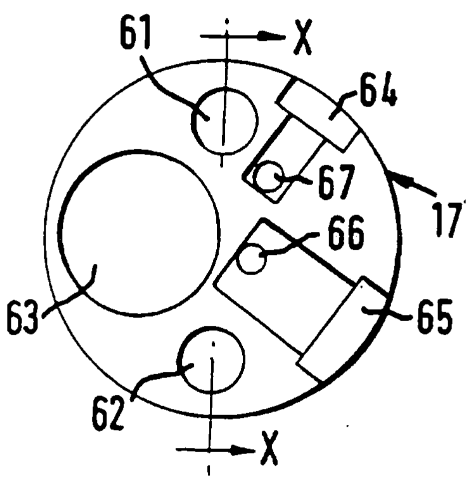

FIG.9

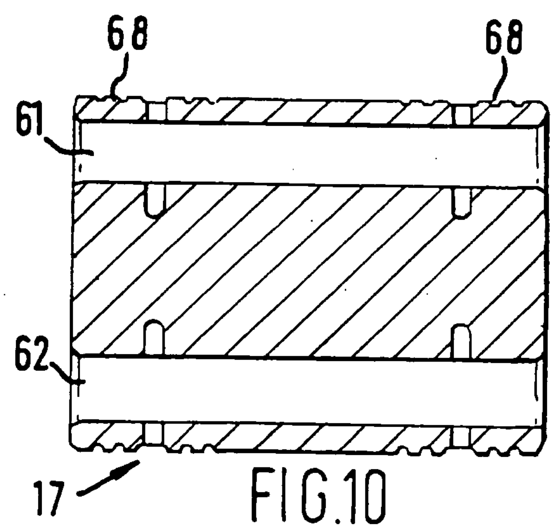

FIG.10

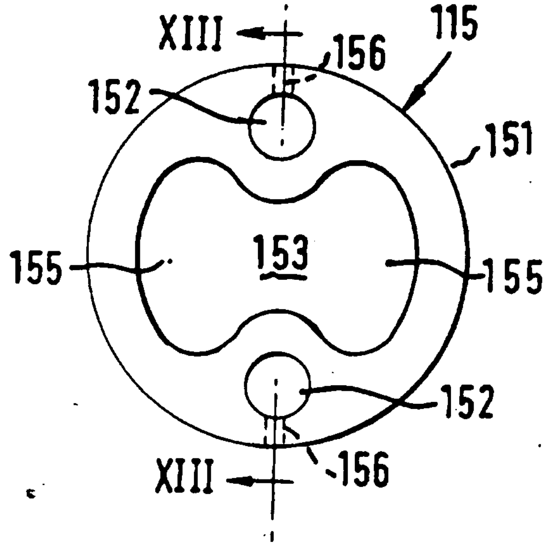

FIG.12

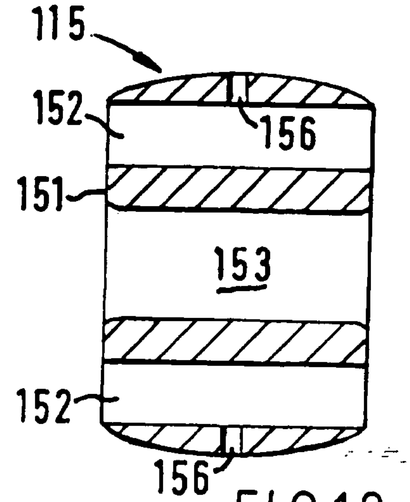

FIG.13

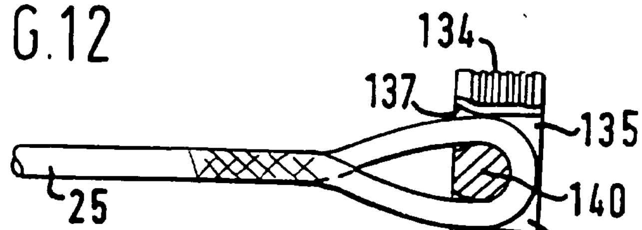

FIG.14

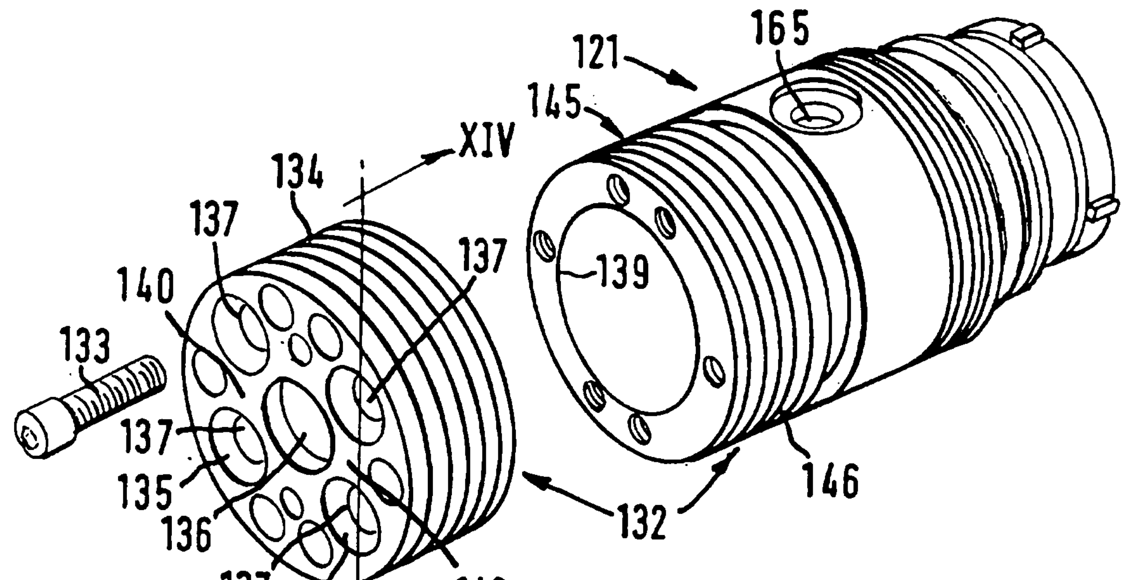

FIG.15

2301328

A Seismic Streamer

This invention relates to seismic streamers which are towed through water behind vessels for seismic exploration and for ship or submarine detection.

Background

Seismic streamers generally comprise hydrophones which are interconnected by power and data cables and which are housed within long flexible tubes.

A seismic streamer may be up to 6 kms in length and therefore is conventionally made up of a large number of sealed elongate modules that are interconnected end to end to make up the streamer. The modules will be connected together through connectors which form end fittings in the modules' end which physically secure the modules together and also provide for electrical connections between modules so that data and power can pass freely the length of the streamer. The streamer may also include electronic transmitting apparatus housed in canisters which are located between streamer modules at various stages along the streamer for broadcasting data which is received by the survey vessel.

The length of the streamer and the drag acting thereon as it is towed through the water, necessitates the use of wire

or rope load bearing members which typically interconnect the end fittings at opposite ends of a streamer module.

In a typical streamer as shown in US Patent 4,638,469 there are three or four equiangularly spaced ropes or wires running the length of the module. Alternatively, in US Patent 5,251,182 the ropes are incorporated within the wall of the surrounding tube. A rope or wire member is typically attached to the respective end fitting by means of a cone cast on to the end of the rope or wire e.g. an epoxy resin cone. The failure point of such an attachment means is unpredictable. Another problem with these types of construction is that the loads in wires or ropes are not evenly distributed as between the wires or ropes when the strand is curved around a storage reel.

A typical streamer module also includes a number of spacers which substantially fill a cross sectional area of the tube. The spacers serve to maintain the internal cross-section of the tube and to keep the rope or wire load bearing members separated from the power and data cables. The module also contains acoustic units having hydrophones, and oil filler blocks. Typically the streamer is given controlled buoyancy, usually neutral buoyancy by filling the voids within the streamer module by a liquid of a particular density. Paraffinic hydrocarbons have been used for this purpose. For example in US Patent 3,518,677 there is described the use of a gelatinised hydrocarbon having a

specific gravity of 0.8 or slightly below.

The disclosure herein provides means for adjusting the buoyancy of a streamer, improved load bearing members, and improved end fitting for the streamer modules.

Statements of Invention

Accordingly there is provided a seismic marine streamer in which hydrophones are housed in elongate flexible tubes which also house a pair of load carrying rope members which pass through a plurality of spacers which substantially fill the internal cross-section of the tube, the internal void within the tube being filled by a liquid, the two load carrying members passing on diametrically opposite sides of each spacer adjacent the outer peripheral margins thereof.

Preferably, the spacers are each formed from a respective material having a particular relative density, the spacers being distributed along the streamer according to their respective densities to achieve a desired buoyancy characteristic.

The spacers may be formed from a variety of materials, preferably moulded plastics having a range of densities or specific gravities from 0.5 - 1.8 for example: low density materials such as epoxy resin filled with microspheres, polypropylene, HD and LD Polyethylene, and relatively high

density materials such as polyurethane resins, acetal resins and phenolformaldehyde moulding compounds. In some cases it might be desirable to use brass or bronze spacers.

Preferably the load bearing rope members are an aromatic polyester material, in particular a liquid crystal polymer fibre which is braided into rope. A typical example is 'Vectran' (registered trademark) manufactured by Hoechst Celanese. The rope may be sheathed in a polyester yarn fabric overbraid to prevent snagging on the internal surface of the tube.

Also according to the invention there is provided a seismic marine streamer in which hydrophones are housed in elongate flexile tubes including a pair of load carrying rope members which pass through a plurality of spacers which substantially fill the internal cross-section of the tube, the internal void within the tube being filled by an aqueous medium, for example sea water, fresh water, or a salt solution, in particular a calcium chloride solution.

Yet another aspect of the present invention provides a connector assembly for sealing the end of a flexible tube of a seismic streamer, the connector assembly having a pair of tube end fittings each with a cylindrical portion with a plurality of cavities therein each of which in use receives a looped end of a rope or wire, and a pin fast with the end fitting is engagable within the loop to

secure the end fitting to a respective rope or wire.

Preferably the pin is integral with the respective end fitting.

The loop connection with the pin forms a flexible connection which is extremely reliable and has predictable load carrying capabilities.

The invention also provides a method of trimming the buoyancy of seismic streamer in which hydrophones are housed in elongate flexible tubes having a plurality of spacers which substantially fill the internal cross-section of the tube, the internal void within the tube being filled by a liquid, wherein the spacers are distributed along the streamer according to the respective densities of the materials from which they are formed so as to achieve a desired buoyancy characteristic.

Description of Drawings

The invention will be described by way of example and with reference to the accompanying drawings in which:-

Fig. 1 is schematic cross-section through a streamer module according to the invention,

Fig. 2 is an isometric view of a small portion of the streamer of Fig. 1.,

Fig. 3 is a cross-section through an end fitting

	for a streamer tube forming one member of a connector assembly for interconnecting streamer modules,
Fig. 4	is a cross section through a connector assembly,
Fig. 5	is view in the direction of arrow A on the inner end of the end fitting of Fig. 3.,
Fig. 6	is an end view of a first spacer used in Fig. 1.,
Fig. 7	is a side view of the spacer in Fig. 6.,
Fig. 8	is a liquid filler used in the streamer of Fig. 1,
Fig. 9	is a section on the line IX-IX of Fig. 8.,
Fig. 10	is a section on the line X-X of Fig. 9,
Fig. 11	is a section on the line XI-Xi of Fig. 9.
Fig. 12	is a front elevation of a second spacer,
Fig. 13	is a section on the line XIII-XIII of Fig.12,
Fig. 14	is a view of the retainer plate of a second end fitting showing a section on the line XIV-XIV of Fig. 15 with a rope member in-situ, and
Fig 15	is an isometric exploded view of the end fitting with its respective retainer plate

Detailed Description of Invention

The invention will be described in general with reference

to Fig. 1 and Fig. 2. There is shown in the drawings a module 10 of a seismic marine steamer. These modules 10 are typically 75-100 meters in length and typically 40 modules may be linked together in a single streamer which is towed behind a ship for seismic exploration of a seabed or lake bottom.

The streamer module 10 comprises an outer flexible tube 11 about 62mm in external diameter and 56mm in internal diameter which is typically formed of a thermoplastic polyurethane e.g. 1185A Elastollan (trademark) available from BASF. The tube 11 houses a plurality of hydrophones 12 which are spaced along the module so that there are about eight hydrophones along a six meter length of tube. The hydrophones 12 are preferably waterproof. An example of a suitable hydrophone is the Benthos RDA hydrophone (available from Benthos Inc. North Falmouth, Maine, USA) The hydrophones are connected in parallel and are held in the centre of the tube by a tubular foam collar 13 or alternatively may be stitched to rope members 25, 26.

A plurality of tubular spacers 15 are located between the hydrophones 12 and are spaced along the length of the tube 11. The spacers 15 substantially fill the cross section of the tube and serve to hold the tube in a circular cross-section. The spacers 15 may also be used as bulk heads dividing each module 10 into separate liquid filled sections.

Each end of the module 10 is closed by an end fitting 21, 22 which forms part of a connector assembly 20 which interconnects two modules, 10. Each end fitting 21, 22 has a respective smaller diameter cylindrical portion 23, 24 respectively onto which an end portion 11A of the tube 11 can be swaged so that the end fittings 21, 22 seal the ends of each module. Extending between the two end fittings 21, 22 are a pair of load carrying rope members 25, 26 which take the towing load when the streamer is towed behind a vessel. The rope members 25, 26 are each secured at each end to a respective end fitting 21 or 22 as will be later described.

The hydrophones 12 spaced along each module 10, and the hydrophones 12 in the different modules are interconnected by data-carrying and power carrying cables 16, so that the connector assemblies 20 also include means for interconnection of the cables 16 between one module and an adjacent module.

Each module 10 also includes at least two filler blocks 17, located in the tube 11 at a location between the end fittings 21, 22. The tube 11 is swaged onto end portions 18 of the filler block 17. The filler block 17, and spacers 15 serve to keep the load carrying rope members 25,26 away from the cables 16. The filler block 17 will be later described in detail but includes means whereby the void within the tube may be filled with a liquid of a

density so as to provide the module with a neutral buoyancy overall when in sea water or fresh water. In some instances the tube may be filled with an aqueous medium such as calcium chloride solution, or sea-water, or is more typically filled with a paraffinic hydrocarbon.

The components within the module will now be described in more detail.

With reference to Figs. 3-5 there is shown a connector assembly 20 having end fittings 21, 22 which are located in the respective end portions 11a of tubes 11. The end fittings 21 and 22 have a titanium body 31 with a cylindrical axially outer end portion 32 which is gripped within the end portions 11a of the tube 11. The end fitting bodies 31 each have a hollow interior in which one half of an electrical pin and socket connector assembly 34 is housed. In this example the socket connector block 34a is located in the male end fitting 21 and the pin connector block 34b is located within the female end fitting 22. The pin and socket connectors 34 are for example thirty seven pin connectors which are connected to the individual data and supply cables 16. The connector blocks 34a or 34b are secured within their end fitting bodies 31 and are held in place by screw threaded rings 36.

The female end fitting 22 has an elongate cylindrical housing portion 38 that extends beyond the pin connector

block 34b away from the inner end portion 32 and has an inner cylindrical wall which accommodates the nose portion 39 of the male end fitting 21 so that the nose portion 39 is sealingly slidable into the housing portion 38. The two end fittings 21, 22 may be held together by a titanium sleeve 41 which is rotatably fixed to the end fitting 22 by bearings 42 and which has an internal screw threaded portion 43 which engages with a like-threaded external portion 44 on the end fitting 21. The end fittings 21, 22 and sleeve 41 form the connector assembly 20 for mechanical and electrical interconnection of streamer modules.

The outer end portion 32 of each end fitting 21, 22 has a substantially cylindrical outer surface 45 over which the end portions 11a of the tube 11 are sealingly attached. The outer cylindrical surface 45 has a pair of diametrically opposite cavities 46 formed therein. Each cavity 46 is in the general form of a 'u' shaped cross sectional channel that extends in a loop to leave an island 47 integral with each end fitting 21,22 projecting radially thereof. The loop shape of the cavity 46 can accommodate an eye-spliced rope end 48 (shown in dotted outline) so that a pin 47 formed by a respective island 47 can project through the eye of the rope to secure the rope to the respective end fitting.

When the eye spliced loop ends 48 of the two rope members 25, 26 are fixed over the pins 47 the tube 11 is pushed

over the respective end fitting body 31. The tube 11 prevents the radial outwards movement of the rope loop and prevents disengagement from the respective pins 47. Furthermore the 'loop' shape of the cavity 46 allows for some pivotal movement between the rope 25, 26 and the end fitting 21, 22 about an axis formed by the pins 47.

In an alternative embodiment shown in Fig. 15 the rope members 25, 26 are attached to their respective end fittings, only one 121 of which is shown, by means of a separable retainer plate 134 forming part of the outer end portion 132 of each end fitting 121. The retainer plate 134 is secured in place by a plurality of bolts 133, preferably six circumferentially spaced bolts, only one of which is shown for convenience, which engage threaded holes 139 on the remainder of the end portion 132.

Each retainer plate 134 (also see Fig 14.) has a pair of internal cavities 135 formed one on each side of a central aperture 136 through which the cables 16 pass. The cavities 135 each comprise a pair of bores 137, opening towards the tube 11, which are interconnected at their other ends by a slot 138 opening towards the connector blocks and forming a U-shaped cavity with an integral pin 140 formed between the two bores 137.

As can be seen in Fig 14, a rope member 25 or 26 is passed through one of the bores 137 passed around the pin 140, and

then passes back on itself through the other bore 137 and is spliced to the rope to form a loop 141. The retainer plate 134 with its ropes attached thereto is secured to the rest of the end fitting by bolts 133 and a tube end portion 11A is then fitted over the assembled outer end portion 132. The external cylindrical surface 145 of the inner end portion 132 has annular grooves 146 formed thereon for attachment of the tube 11. The end fitting 121 also includes an inlet port 165 for filling the tube 11 with liquid.

The two rope members 24, 25 are formed from an aromatic polyester material having liquid crystal polymer phase. An example of this material is 'Vectran' manufactured by Hoechst Celanese. The two rope members should be capable of taking a load of at least 14000 lbs (6250 Kg) and preferably between 18-19,000 lbs. and have a preferred structure of 12 strand single braid rope having a nominal 8mm diameter and preferably 9mm diameter. The use of two load carrying members 25, 26 and the provision of the movement between the rope and the end fittings helps to reduce the stresses within a streamer module when the streamer is rolled up for storage on a drum or reel. The spliced loops and pin connectors should each take a load of about 14,000 lbs. The ropes 25, 26 may be covered in a sheath, preferably a polyester fabric braid sheath, to reduce snagging of the braid on the inside of the tube.

The spacers 15 are shown in Figures 6 and 7 and have substantially barrel shaped bodies 51 which in use will fill the internal cross-section of the tube 11. Each spacer 15 has a pair of diametrically opposite holes 52 to accommodate the rope members 25, 26. The spacers 15 also have four circumferentially spaced apertures 53 located radially inwardly therein, which are spaced apart by radial struts 54. The apertures 53 allow for passage of the cables 16. The spacer 15 has improved radial load carrying capacity because of the cruciform arrangement of struts 54 at its centre.

The spacers 15 may also be used to isolate sections of the module 10 by sealing the rope members 25, 26 and cables 16 to the spacer where they pass therethrough, and other apertures not in use being sealed.

The spacers 15 are moulded from a plastics material by injection, or compression moulding techniques. The spacers are made from material of a variety of specific gravities, so that some spacers may be made of polypropylene having a relative density of 0.89 - 0.90 and some spacers may be made of polyacetal resin having a density of about 1.45 - 1.5. Other materials such as polyurethane elastomer having a density of 1.2, or phenolic moulding compounds which may have a density of up to 1.8, bronze, brass, or epoxy resin filled with glass microspheres to give a desired density as low as 0.5, could also be used. By having spacers formed

of different materials having different densities it is possible to trim the buoyancy of the module 10 by means of the disposition of the spacers, and selection of their material make-up.

An alternative form of the polyurethane spacer 115 is, for example, made from 'Isoplast' from Dupont, and is shown in Figures 12 and 13. The polyurethane resin may be a glass reinforced resin if desired. The spacer 115 has a substantially barrel shaped body 151 as before, with a pair of diametrically opposite axially exterior holes 152 to accommodate the rope members 25, 26. The spacer 115 has a large central aperture 153 shaped in the form of a bow tie with the cables 16 passing through the larger portions 155 of the aperture 153. A pair of radial holes 156 are aligned with the axial holes 152 for the ropes. These holes are for injecting adhesive, for example an epoxy resin, for securing the spacer to the respective rope members.

The filler block 17 is shown in Figures 8 to 11. The block 17 is a substantially cylindrical block formed by moulding a plastics material, preferably an acetal resin. Each block has a pair of diametrically opposed longitudinal passageways 61, 62 passing therethrough to accommodate the rope members 25, 26 and an off set larger diameter longitudinal passageway 63 for accommodating passage of the

cables 16 therethrough. A radial vent port 64 and a radial inlet port 65 are located at the centre of each block 17. The inlet port 65 being connected into the tube by means of an axial passageway 66 and the vent port 64 is connected into the tube by two axial passageways 67. The two ports are provided with sealing caps (not shown) to seal the tube 11 after filling with a low density liquid and venting.

The end portions 18 of the filler block has annular grooves 67 formed on external surface thereof to help retain the tube 11 which is swaged thereon.

The filler block 17 may be formed from materials such as acetal resin, bronze, brass, phenolics, etc. selected for a particular density requirement to assist trim the buoyancy of the module 10.

The cavity within the module 10 is preferably filled with an electrically inert liquid, typically a paraffin hydrocarbon, or a vegetable oil which excludes air from the module and gives a predetermined overall buoyancy. One example of a paraffin hydrocarbon is an SPC process oil, available from Multisol Limited, based in England. These oils are restructured mineral oils having a very high purity and which have been dewaxed. They are water white, odourless, extremely stable and have substantially no aromatics that might attack other materials used in the module 10. Such materials have a density from 0.845 -

0.869 and kinematic viscosities as measured by ASTM D445 of between 3.35 and 35 centistokes at 40 degrees centigrade and between 1.31 and 5.6 centistokes at 100 degrees centigrade. Alternatively the cavity may be filled with other hydrocarbon paraffins, such as Isopar M available from Exxon, or Shell Sol T, which have a lower density of about 0.7, or the cavity may be filled with an aqueous medium as previously described.

The above described construction of streamer modules provides a compact streamer module which has a light chassis.

Claims

1. A seismic marine streamer comprising hydrophones housed in elongate flexible tubes, a pair of load carrying rope members, and a plurality of spacers which substantially fill the internal cross-section of the tube, the internal void within the tube being filled by a liquid, wherein the two rope carrying members pass through each spacer on diametrically opposite sides thereof adjacent the outer peripheral margin of each spacer.

2. A streamer as claimed in Claim 1, wherein the load carrying rope members have a nominal diameter of at least 8mm and a breaking load of at least 14,000 lbs.(6250 Kg).

3. A streamer as claimed in Claim 1 or Claim 2, wherein the rope members are each covered by a polyester fabric sheath.

4. A streamer as claimed in any one of Claims 1 to 3, wherein the spacers are each formed from a respective material having a particular relative density, the spacers being distributed along the streamer according to their respective densities to achieve a desired buoyancy characteristic.

5. A streamer as claimed in Claim 4 wherein the spacers

are moulded plastic spacers formed from materials having densities in the range of 0.5 - 1.8.

6. A streamer as claimed in Claim 4 or Claim 5, wherein the spacers are each made from one of polypropylene, polyacetal or polyurethane resin.

7. A streamer as claimed in any one of Claims 1 to 6, wherein each spacer has apertures therein through which the rope members and electrical cables pass, the apertures being located in the spacer to leave a cruciform load support in the centre thereof.

8. A streamer as claimed in any one of Claims 1 to 7 wherein the load carrying rope members are formed from liquid crystal polymer fibre which is braided or twisted into rope.

9. A seismic streamer as claimed in any one of Claims 1 to 8, wherein the liquid is an aqueous medium.

10. A seismic marine streamer as claimed in any one of Claims 1 to 9, wherein the streamer is formed from elongate modules each of which comprises a length of flexible tube sealed at each end by an end fitting, spacers distributed along the length of the module, and the two end fittings are interconnected by the two load carrying rope members each of which has a rope loop formed at each end thereof,

each rope loop being accommodated in a respective cavity formed in a respective end fitting, and a pin fast within each end fitting engages within the loop to secure the respective rope member to said end fitting.

11. A streamer as claimed in Claim 10, wherein each pin is formed integrally with the respective end fitting.

12. A streamer as claimed in Claim 10 or Claim 11 in which each respective end fitting includes a separable retainer plate which has a pair of axially oriented internal cavities therein in which said pins are located.

13. A seismic streamer as claimed in Claim 10 or claim 11, wherein each cavity is formed in an externally outer surface of a respective end fitting, and the respective pin associated with each cavity is surrounded by said cavity, the flexible tube attached to the end fitting preventing radially outward movement of the rope loop relative to the end fitting.

14. A seismic streamer as claimed in any one of claims 10 to 13, wherein each cavity is in the form of a 'u' shaped channel extending in a loop so that when the rope is located within the cavity, it allows the end fitting to rotate relative to the rope loop about an axis formed by the pin.

15. A connector assembly for sealing the end of a flexible tube for a seismic steamer, the assembly comprising a pair of tube end fittings each having a cylindrical portion with a plurality of cavities therein each of which in use receives a looped end of a rope, and a pin fast with the end fitting is engagable within the loop to secure the end fitting to a respective rope member.

16. A connector as claimed in Claim 15 wherein each pin is formed integrally with the end fitting.

17. A connector as claimed in Claims 15 or Claim 16 wherein each cavity is a 'u' shaped cross-sectional channel extending in a curving loop around the pin.

18. A connector as claimed in Claim 15, wherein each respective end fitting includes a separable retainer plate and said cavities are formed in the retainer plate and said pins are located within said cavities.

19. A connector as claimed in Claim 15 wherein the cavities on each end fitting are formed in the outer surface of said cylindrical portion, and the tube affixed to the end fitting prevents radially outward movement of the rope loop relative to the end fitting.

20. A connector as claimed in claim 18, wherein the loops in the rope members are formed by eye splices therein.

The Patent Office

21

Application No:	GB 9610541.6	**Examiner:**	Alan Habbijam
Claims searched:	1-14	**Date of search:**	23 September 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): B7V (VHS) : G1G (GEEA, GEEH)

Int Cl (Ed.6): G01V 1/18, 1/20, 1/38 : B63B 21/66.

Other: Online:WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO 93/03402 A1 (SHELL OIL CO) see stress members 21, Fig 5 in particular.	1,7&8.
X	US 4951265 (BUCKLES) see strength members 22, Figs 2&3.	1.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		